# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2002-208158
(43)Date of publication of application : 26.07.2002

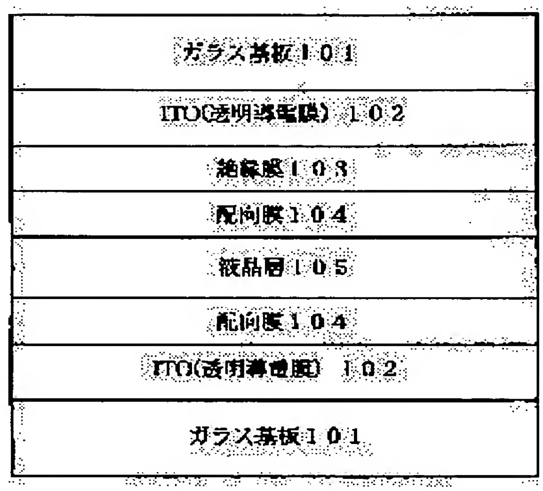
(51)Int.Cl. G11B 7/135
G02F 1/13

(21)Application number : 2001-003194
(22)Date of filing : 11.01.2001

(71)Applicant : CITIZEN WATCH CO LTD
(72)Inventor : HASHIMOTO NOBUYUKI

## (54) LIQUID CRYSTAL ELEMENT AND OPTICAL PICKUP USING THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain high transmittance to light having a specific wavelength and to minimize the fluctuation of light transmittance when a liquid crystal is driven by optimizing the thin film structure of a liquid crystal element.
SOLUTION: The relation between the film respective thickness and refractive indices of an ITO film, an insulating film and an alignment film which are constituents of the liquid crystal element are optimized.






LEGAL STATUS
[Date of request for examination]
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]
[Date of registration]
[Number of appeal against examiner's decision of rejection]
[Date of requesting appeal against examiner's decision of rejection]
[Date of extinction of right]

---

CLAIMS

---

[Claim(s)]
[Claim 1] The transparence substrate of a pair with which the laminating of ITO and the orientation film was carried out one by one comes to meet. It is a liquid crystal device for modulating the phase of the homogeneous light which is equipped with a liquid crystal layer between the orientation film concerned and by which the insulator layer was formed between the orientation film on one [ at least ] transparence substrate, and ITO, or laser light. By 3000nm or more 8000nm or less, the effective refractive index to the incident light of a liquid crystal molecule changes in the or more 1.4 1.8 or less range, and said liquid crystal thickness the refractive index to incident light The liquid crystal device characterized by for 1.75**0.1 and the orientation film being [ said transparence substrate / for 1.7**0.1 and an insulator layer ] 1.63**0.1 for 1.5**0.2 and ITO, and orientation thickness being 70**30nm.
[Claim 2] 60+190n or a−0.6, and b are the liquid crystal device according to claim 1 which the relation between said thickness Ynm of ITO and the thickness Xnm of said insulator layer filled about Y=aX+bxlambda /650 (wavelength of the incident light lambda was described to be per nm), and was characterized by a−0.4 and b being 170+190n (n being an integer).
[Claim 3] The liquid crystal device according to claim 1 characterized by for said thickness of ITO being x(120**30) lambda/650nm, and insulator layer thickness being x(70**30) lambda/650nm.
[Claim 4] The optical pickup using the liquid crystal device to which said liquid crystal device carries out the description of being the liquid crystal device of a publication to any 1 term of claim 1 thru/or claim 3 in the optical pickup equipped with the liquid crystal device for aberration amendment.

---

[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] It is related with the optical pickup equipped with the liquid crystal device for aberration amendment, and it.
[0002]
[Description of the Prior Art] In order to make an understanding of the conventional technique easy, the phase modulation of the light using the light transmission property of a well-known optical thin film, the optical structure of a liquid crystal device, and a liquid crystal device is explained briefly. it is further about a transparent thin film on transparent substrates, such as a glass substrate, first — it is — the optical thin film applied to the multilayer is considered. Since it consists of transparent ingredients at this time, regardless of wavelength, light transmittance is fixed and becomes about 100%. However, except for the case where the refractive index of all the thin films that contain a glass substrate in fact is the same, light transmittance is determined by the refractive index of a transparence substrate and each thin film, and the thickness of each thin film and the wavelength lambda of light by the cross protection of light. That is, permeability changes with wavelength. Therefore, in specific conditions, the optical thin film which penetrates only specific wavelength can be realized, and it is well known as an interference filter. Moreover, a scaling exists in the thickness and wavelength of a thin film about permeability. That is, permeability is the same, if thickness of a thin film is also set to 1/n when wavelength drops to 1/n.
[0003] Next, the optical structure of a general liquid crystal device is explained. It is constituted as a main component in order of a glass substrate, ITO (transparence electric conduction film), an insulator layer, the orientation film, a liquid crystal layer, the orientation film, ITO, and a glass substrate. As for a glass substrate, the glass whose refractive index is about 1.5 is used. moreover, mass-production nature, constraint of an ingredient, etc. — ITO — a refractive index — 1.7 to about 2, and thickness — about 100 to 3000nm, and an insulator layer — a refractive index is used for about 1.7 and thickness, about 50 to 200nm is used for about 1.63 and thickness, and, as for about 50 to 300nm, and the orientation film, the refractive index has a diaphragm structure. Then, the phase modulation principle of the light using an parallel orientation mold or a perpendicular orientation mold liquid crystal device is explained. Drawing 6 (a) and (b) express typically actuation of an parallel orientation mold liquid crystal device. The liquid crystal molecule 602 is inserted between the glass substrates 601 with which the transparence electric conduction film was applied like drawing 6 (a), and the thickness is d. As for the liquid crystal molecule 602, both glass substrates 601 arranged the direction of a major axis with Y shaft orientations for Y shaft orientations, and orientation shaft orientations are located in a line in parallel. In order to progress looking at the direction of a major axis of the liquid crystal molecule 602 if the linearly polarized light 603 of Y shaft orientations carries out incidence to this liquid crystal device, that optical path length is set to n1xd. n1 is the refractive index of the direction of a major axis of the liquid crystal molecule 602, and becomes an effective refractive index to the linearly polarized light 603 here.
[0004] Next, if sufficiently high electric field are given to Z shaft orientations as shown in

drawing 6 (b), the liquid crystal molecule 602 will arrange the major axis in the direction of electric field, and will be located in a line. In order to progress looking at the direction of a minor axis of the liquid crystal molecule 602 if the linearly polarized light 603 of Y shaft orientations carries out incidence to this liquid crystal device, that optical path length is set to n2xd. n2 is the refractive index of the direction of a minor axis of the liquid crystal molecule 602 here. Therefore, before and after giving electric field, only in x(n1−n2) d, the optical path length changes, and the phase of the incidence linearly polarized light 603 changes and carries out outgoing radiation only of 2pi(n1−n2) x d/lambda (lambda is the wavelength of incident light). An intermediate state is also realizable by adjusting the electric field given to a liquid crystal molecule. Therefore, if a liquid crystal molecule is partially driven using the inclination electric field produced with the divided transparent electrode or a high resistance electrode, it is possible to give phase distribution to the incidence linearly polarized light 603. Moreover, although the basic actuation is the same also in the liquid crystal device by which perpendicular orientation was carried out, the time of the time of not giving electric field giving electric field in the state of drawing 6 (b) will be in the condition of drawing 6 (a).

[0005] In recent years, in the optical disk of the high density of DVD etc., the liquid crystal device attracts attention as an aberration amendment component of optical system. This tends to insert a liquid crystal device into the laser light source and the optical path of the optical pickup equipped with the objective lens, and tends to amend the phase turbulence of the light by the comatic aberration which an optical disk substrate generates by the ** pure thing, and the spherical aberration generated in case a multilayer disk substrate is read, i.e., the turbulence of the wave front of light. According to the amount of aberration generated at this time, refractive-index distribution is given to a liquid crystal device with the divided transparent electrode, and the wave front of laser light is amended.

[0006]

[Problem(s) to be Solved by the Invention] However, in the optical element for laser beam study systems to which laser power was restricted like an optical pickup, light transmittance is an important element. In the case of the optical pickup using blue laser with a wavelength of about 450nm which attracts attention especially recently, the luminous efficiency of blue laser falls compared with red laser with a conventional wavelength of about 650nm. Moreover, since laser light generates the light of specific sharp wavelength, it becomes important [ the light transmittance in the wavelength ]. The effective refractive index of a liquid crystal layer changes by driving a liquid crystal device further with a diaphragm structure on the other hand. Therefore, when using it by laser light or the homogeneous light, even if it drives liquid crystal so that the diaphragm structure of a liquid crystal device may be optimized to the wavelength to be used and permeability may serve as max and, it is desirable to make it fluctuation of light transmittance serve as min. However, the conventional liquid crystal device is not as a phase modulation component, and the subject has developed the display application which used the optical shutter effectiveness over the white light by using with a polarizing plate. Therefore, the optimization design of the diaphragm structure of a liquid crystal device was not carried out to laser optical system. Moreover, generally, although the parallel orientation mold liquid crystal which is a phase modulation mold was often used for general laser optical system, since laser light had very big power, it did not have to make light transmittance a problem and did not need to optimize the diaphragm structure of a liquid crystal device.

[0007]

[Means for Solving the Problem] The simulation result of the light reflex property in the homogeneous light with a wavelength of 650nm at the time of changing the thickness and the refractive index of ITO to drawing 7 in a liquid crystal device is shown. As a liquid crystal device, it is constituted in order of a glass substrate, ITO, an insulator layer, the orientation film, a liquid crystal layer, the orientation film, ITO, and a glass substrate. the refractive index of a glass substrate — for the refractive index of 70nm and the orientation film, 1.63 and thickness are [ the refractive index of 1.49 and an insulator layer / 1.75 and thickness / 1.6 and the thickness of the effective refractive index of 70nm and a liquid crystal layer ] 5000nm. In a Y-axis, the thickness of ITO and the X-axis express the refractive index of ITO, and the Z-axis expresses

the rate of a light reflex with drawing 7 . It is stable, even if the minimal value of the 1st reflection factor has the thickness of ITO near 110nm from drawing 7 and the refractive index of ITO changes. Moreover, a reflection factor falls, so that the refractive index of ITO is close to 1.6, and the fluctuation to change of ITO thickness also becomes small. Therefore, although, as for light transmittance, the thickness of ITO is served as to 110nm and the refractive index serves as max and stability by 1.6 under this condition, the value which can be actually chosen as an ITO refractive index is 1.7. Moreover, it also turns out that the minimal value of the 2nd reflection factor has the thickness of ITO near 200nm from drawing 4 .

[0008] In use of an actual liquid crystal device, the effective refractive index changes in operating a liquid crystal device. Drawing 8 is as a result of [ of the light reflex property at the time of changing the thickness of an insulator layer, and the effective refractive index of a liquid crystal layer ] a simulation. ITO thickness is 110nm, a refractive index is 1.7, and other conditions are the same as the case of drawing 7 . As for the effective refractive index of a liquid crystal layer, and the Z-axis, the thickness of an insulator layer and the X-axis express [ a Y-axis ] the rate of a light reflex. Even if the saddle point of the rate of a light reflex exists [ the thickness of an insulator layer ] near 70nm and the effective refractive index of a liquid crystal layer changes from drawing 8 , high light transmittance is realized stably.

[0009] Drawing 9 is as a result of [ of the light reflex property at the time of changing the thickness of ITO, and the thickness of an insulator layer in a liquid crystal device ] a simulation. The refractive index of ITO is 1.7 and other conditions are the same as the case of drawing 7 . Y-axes are [ the thickness of ITO and the X-axis of the thickness of an insulator layer and the Z-axis ] the rates of a light reflex. The saddle point of the rate of a light reflex exists from drawing 9 , it is expressed with linear expression Y=aX+b, and it turns out that 60+190n or a-0.6, and b of a-0.4 and b are 170+190n (n is an integer). That is, if the group of the ITO thickness which fills the relation of this linear expression about, and insulator layer thickness is chosen, light transmittance serves as max and is stable also to fluctuation of thickness. This conditional expression cannot be used if wavelength changes, since it is a time of the wavelength of incident light being 650nm. If it takes into consideration that there is a scaling in thin film thickness and wavelength as explanation of the light transmission property of the thin film of the conventional technique described, a previous linear expression will be set to Y=aX+bxlambda /650 (wavelength of the incident light lambda was described to be per nm), and will be generalized to operating wavelength. Of course, the thickness of the orientation film is also doubled lambda/650 in that case.

[0010] In the previous simulation, it calculated from the thin film matrix method which is well-known technique (from 49 pages to for example, the Junpei work in a crossing, the optical introduction 2, Asakura Publishing, and 53 pages). This calculates the whole thin film matrix by the multiplication of each thin film matrix, when the matrix of 2x2 described from the refractive index n of a thin film, thickness d, and the operating wavelength lambda describes the optical transfer characteristics of a thin film and the laminating of the thin film is carried out, if it says simply. It is the technique of calculating the rate of a light reflex, or light transmittance from the result.

[0011]

[Embodiment of the Invention] An example of the operation gestalt of this invention is shown in drawing 1 . The liquid crystal devices of this invention are the following configurations. That is, the glass substrate 101 ITO102 and whose orientation film 104 are the transparence substrates of the pair by which the laminating was carried out one by one comes to meet, and it has the liquid crystal layer 105 between the orientation film 104 concerned, and it is the configuration that the insulator layer 103 was formed between the orientation film 104 on one [ at least ] transparence substrate, and ITO102, and the liquid crystal device for modulating the phase of the homogeneous light or laser light as an application is considered as the fundamental configuration. By this invention, by 3000nm or more 8000nm or less, an effective refractive index [ especially as opposed to the incident light of a liquid crystal molecule ] changes in the or more 1.4 1.8 or less range, and liquid crystal thickness the refractive index to incident light Said transparence substrate has the greatest description at the place which offers the liquid crystal

device characterized by for 1.75**0.1 and the orientation film being [ for 1.7**0.1 and an insulator layer ] 1.63**0.1 for 1.5**0.2 and ITO, and orientation thickness being 70**30nm. Furthermore, with the gestalt of this operation, optimization is attained in the conditions as follows in detail. namely, the glass substrate 101 -- for 0.7mm in a refractive index 1.49 and thickness, and ITO102, as for 70nm in a refractive index 1.63 and thickness, and the liquid crystal layer 105, a refractive index 1.75, thickness Xnm, and the orientation film 104 is [ a refractive index 1.7, thickness Ynm, and an insulator layer 103 / the effective refractive index of the until / 1.5 to 1.7 / adjustable and thickness ] 5000nm. The thickness Y of ITO102 and the thickness X of an insulator layer 103 fill the following relational expression here. Y=aX+bxlambda /650. a-0.4 and b are the wavelength of the incident light 60+190n or a-0.6, and b were described by 170+190n (n is an integer), and lambda was described to be per nm here. Furthermore, it is used for the optical pickup equipped with the laser light source, the objective lens, and the liquid crystal device for aberration amendment as an application using the liquid crystal device of the above-mentioned publication, offer of the liquid crystal device by which permeability was optimized by the optimum conditions of the proper of each configuration of said liquid crystal device is enabled, and it can become still more possible to satisfy the function as an optical pickup using this liquid crystal device.

[0012] (Example) The example of this invention is shown in drawing 2 . a glass substrate 201 -- 0.7mm in a refractive index 1.49 and thickness, and ITO202 -- 120nm in a refractive index 1.7 and thickness, and an insulator layer 203 -- 70nm in a refractive index 1.75 and thickness, and the orientation film 204 -- as for 70nm in a refractive index 1.63 and thickness, and the liquid crystal layer 205, permeability is optimized [ the wavelength of incident light ] for the refractive index to 650nm to the until [ 1.5 to 1.7 ] adjustable by 5000nm, as for thickness.

[0013] Drawing 3 is a light reflex property over light with a wavelength of 650nm in the liquid crystal device of drawing 2 , an axis of abscissa is the effective refractive index of liquid crystal, and an axis of ordinate is a rate of a light reflex. Even if the effective refractive index of liquid crystal changes from drawing 3 , fluctuation of a reflection factor is understood are pressed down to about 1% at the maximum. Therefore, if a nonreflective coat is given to the glass substrate of this liquid crystal device, 99% or more of permeability can be obtained theoretically.

[0014] Drawing 4 shows other examples of this invention. a glass substrate 401 -- 0.7mm in a refractive index 1.49 and thickness, and ITO402 -- 74nm in a refractive index 1.7 and thickness, and an insulator layer 403 -- 43nm in a refractive index 1.75 and thickness, and the orientation film 404 -- as for 43nm in a refractive index 1.63 and thickness, and the liquid crystal layer 405, permeability is optimized [ the wavelength of incident light ] for the refractive index to 400nm to the until [ 1.5 to 1.7 ] adjustable by 5000nm, as for thickness. That is, the scaling mentioned above in the liquid crystal device of the structure of drawing 2 is performed, the refractive index of each film does not change but thickness has become 400/650 time. However, since a glass substrate is not a thin film, the scaling is meaningless. Moreover, although liquid crystal thickness originally needs a scaling, since thickness is decided as there being refractive-index fluctuation at the time of a drive from the optical conditions to be used, the object of a scaling has not carried out.

[0015] Drawing 5 is other examples of this invention, and is applied to the pickup optical system of the optical disk equipped with the well-known liquid crystal aberration amendment device. Laser light 502 which carried out outgoing radiation from the laser light source 501 with a wavelength of 650nm is made into parallel light with a collimate lens 503, penetrates a liquid crystal device 504, and is condensed on an optical disk 506 with an objective lens 505. ITO of a liquid crystal device 504 is constituted by the division electrode, and can display the pattern of arbitration. When the substrate of an optical disk inclines, or thickness changes and light wave side aberration occurs, a liquid crystal device 504 is driven with the aberration amendment signal 507, and aberration amendment is performed serially. Since the optical structure of a liquid crystal device 504 is the same as the component of drawing 2 , even if it drives with the aberration amendment signal 507, fluctuation of light transmittance is 1% or less, and the theoretical light transmittance at the time of giving a nonreflective coat to the glass substrate of a liquid crystal device 504 is 99% or more.

[0016] Drawing 10 is drawing showing the light reflex property of the liquid crystal optical element by this invention. 1.9 was used as a refractive index of ITO. Other conditions are the same as the liquid crystal optical element by this invention. Compared with drawing 8 in connection with this invention, a reflection factor reaches also to a maximum of 10%, and a saddle point with little reflection factor fluctuation in a liquid crystal drive cannot be seen clearly, either.
[0017] Next, drawing 11 is drawing showing the light reflex property of the liquid crystal optical element by this invention. Thickness of ITO was set to 170nm. Other conditions are the same as the liquid crystal optical element by this invention. It compares drawing 3 and it turns out that the reflection factor is sharply changed [ which is concerned with this invention ] with 2% or more. Therefore, the above explanation shows that optimization of each components which constitute a liquid crystal device is important.
[0018]
[Effect of the Invention] If the liquid crystal device by this invention is used so that clearly from old explanation, light transmittance can be optimized to the homogeneous light of arbitration. That is, even when high light transmittance and liquid crystal are driven, fluctuation of light transmittance can be pressed down low. Moreover, even if it changes thickness somewhat in manufacture of a liquid crystal device, there is little permeability change. The efficiency for light utilization of optical system will become high, and this liquid crystal device will contribute also to low electrification of a device, if it is used as the aberration amendment component and light wave side controlling element of the optical system of pickup of an optical disk, a laser beam printer, etc.
[0019] Moreover, although the liquid crystal device was optimized to specific wavelength in this invention, optimizing to two or more wavelength is also possible. In that case, the engine performance falls rather than optimization in monochrome.

---

[Translation done.]

## TECHNICAL FIELD

[Field of the Invention] It is related with the optical pickup equipped with the liquid crystal device for aberration amendment, and it.

[Translation done.]

## PRIOR ART

[Description of the Prior Art] In order to make an understanding of the conventional technique easy, the phase modulation of the light using the light transmission property of a well-known optical thin film, the optical structure of a liquid crystal device, and a liquid crystal device is explained briefly. it is further about a transparent thin film on transparent substrates, such as a glass substrate, first — it is — the optical thin film applied to the multilayer is considered. Since it consists of transparent ingredients at this time, regardless of wavelength, light transmittance is fixed and becomes about 100%. However, except for the case where the refractive index of all the thin films that contain a glass substrate in fact is the same, light transmittance is determined by the refractive index of a transparence substrate and each thin film, and the thickness of each thin film and the wavelength lambda of light by the cross protection of light. That is, permeability changes with wavelength. Therefore, in specific conditions, the optical thin film which penetrates only specific wavelength can be realized, and it is well known as an interference filter. Moreover, a scaling exists in the thickness and wavelength of a thin film about permeability. That is, permeability is the same, if thickness of a thin film is also set to 1/n when wavelength drops to 1/n.
[0003] Next, the optical structure of a general liquid crystal device is explained. It is constituted as a main component in order of a glass substrate, ITO (transparence electric conduction film), an insulator layer, the orientation film, a liquid crystal layer, the orientation film, ITO, and a glass substrate. As for a glass substrate, the glass whose refractive index is about 1.5 is used. moreover, mass-production nature, constraint of an ingredient, etc. — ITO — a refractive index — 1.7 to about 2, and thickness — about 100 to 3000nm, and an insulator layer — a refractive index is used for about 1.7 and thickness, about 50 to 200nm is used for about 1.63 and thickness, and, as for about 50 to 300nm, and the orientation film, the refractive index has a diaphragm structure. Then, the phase modulation principle of the light using an parallel orientation mold or a perpendicular orientation mold liquid crystal device is explained. Drawing 6 (a) and (b) express typically actuation of an parallel orientation mold liquid crystal device. The liquid crystal molecule 602 is inserted between the glass substrates 601 with which the transparence electric conduction film was applied like drawing 6 (a), and the thickness is d. As for the liquid crystal molecule 602, both glass substrates 601 arranged the direction of a major axis with Y shaft orientations for Y shaft orientations, and orientation shaft orientations are located in a line in parallel. In order to progress looking at the direction of a major axis of the liquid crystal molecule 602 if the linearly polarized light 603 of Y shaft orientations carries out incidence to this liquid crystal device, that optical path length is set to n1xd. n1 is the refractive index of the direction of a major axis of the liquid crystal molecule 602, and becomes an effective refractive index to the linearly polarized light 603 here.
[0004] Next, if sufficiently high electric field are given to Z shaft orientations as shown in drawing 6 (b), the liquid crystal molecule 602 will arrange the major axis in the direction of electric field, and will be located in a line. In order to progress looking at the direction of a minor axis of the liquid crystal molecule 602 if the linearly polarized light 603 of Y shaft orientations carries out incidence to this liquid crystal device, that optical path length is set to n2xd. n2 is the refractive index of the direction of a minor axis of the liquid crystal molecule 602 here.

Therefore, before and after giving electric field, only in x(n1−n2) d, the optical path length changes, and the phase of the incidence linearly polarized light 603 changes and carries out outgoing radiation only of 2pi(n1−n2) x d/lambda (lambda is the wavelength of incident light). An intermediate state is also realizable by adjusting the electric field given to a liquid crystal molecule. Therefore, if a liquid crystal molecule is partially driven using the inclination electric field produced with the divided transparent electrode or a high resistance electrode, it is possible to give phase distribution to the incidence linearly polarized light 603. Moreover, although the basic actuation is the same also in the liquid crystal device by which perpendicular orientation was carried out, the time of the time of not giving electric field giving electric field in the state of drawing 6 (b) will be in the condition of drawing 6 (a).
[0005] In recent years, in the optical disk of the high density of DVD etc., the liquid crystal device attracts attention as an aberration amendment component of optical system. This tends to insert a liquid crystal device into the laser light source and the optical path of the optical pickup equipped with the objective lens, and tends to amend the phase turbulence of the light by the comatic aberration which an optical disk substrate generates by the ** pure thing, and the spherical aberration generated in case a multilayer disk substrate is read, i.e., the turbulence of the wave front of light. According to the amount of aberration generated at this time, refractive-index distribution is given to a liquid crystal device with the divided transparent electrode, and the wave front of laser light is amended.

---

[Translation done.]

## EFFECT OF THE INVENTION

[Effect of the Invention] If the liquid crystal device by this invention is used so that clearly from old explanation, light transmittance can be optimized to the homogeneous light of arbitration. That is, even when high light transmittance and liquid crystal are driven, fluctuation of light transmittance can be pressed down low. Moreover, even if it changes thickness somewhat in manufacture of a liquid crystal device, there is little permeability change. The efficiency for light utilization of optical system will become high, and this liquid crystal device will contribute also to low electrification of a device, if it is used as the aberration amendment component and light wave side controlling element of the optical system of pickup of an optical disk, a laser beam printer, etc.
[0019] Moreover, although the liquid crystal device was optimized to specific wavelength in this invention, optimizing to two or more wavelength is also possible. In that case, the engine performance falls rather than optimization in monochrome.

[Translation done.]

## TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, in the optical element for laser beam study systems to which laser power was restricted like an optical pickup, light transmittance is an important element. In the case of the optical pickup using blue laser with a wavelength of about 450nm which attracts attention especially recently, the luminous efficiency of blue laser falls compared with red laser with a conventional wavelength of about 650nm. Moreover, since laser light generates the light of specific sharp wavelength, it becomes important [ the light transmittance in the wavelength ]. The effective refractive index of a liquid crystal layer changes by driving a liquid crystal device further with a diaphragm structure on the other hand. Therefore, when using it by laser light or the homogeneous light, even if it drives liquid crystal so that the diaphragm structure of a liquid crystal device may be optimized to the wavelength to be used and permeability may serve as max and, it is desirable to make it fluctuation of light transmittance serve as min. However, the conventional liquid crystal device is not as a phase modulation component, and the subject has developed the display application which used the optical shutter effectiveness over the white light by using with a polarizing plate. Therefore, the optimization design of the diaphragm structure of a liquid crystal device was not carried out to laser optical system. Moreover, generally, although the parallel orientation mold liquid crystal which is a phase modulation mold was often used for general laser optical system, since laser light had very big power, it did not have to make light transmittance a problem and did not need to optimize the diaphragm structure of a liquid crystal device.

[Translation done.]

## MEANS

[Means for Solving the Problem] The simulation result of the light reflex property in the homogeneous light with a wavelength of 650nm at the time of changing the thickness and the refractive index of ITO to drawing 7 in a liquid crystal device is shown. As a liquid crystal device, it is constituted in order of a glass substrate, ITO, an insulator layer, the orientation film, a liquid crystal layer, the orientation film, ITO, and a glass substrate. the refractive index of a glass substrate — for the refractive index of 70nm and the orientation film, 1.63 and thickness are [ the refractive index of 1.49 and an insulator layer / 1.75 and thickness / 1.6 and the thickness of the effective refractive index of 70nm and a liquid crystal layer ] 5000nm. In a Y-axis, the thickness of ITO and the X-axis express the refractive index of ITO, and the Z-axis expresses the rate of a light reflex with drawing 7 . It is stable, even if the minimal value of the 1st reflection factor has the thickness of ITO near 110nm from drawing 7 and the refractive index of ITO changes. Moreover, a reflection factor falls, so that the refractive index of ITO is close to 1.6, and the fluctuation to change of ITO thickness also becomes small. Therefore, although, as for light transmittance, the thickness of ITO is served as to 110nm and the refractive index serves as max and stability by 1.6 under this condition, the value which can be actually chosen as an ITO refractive index is 1.7. Moreover, it also turns out that the minimal value of the 2nd reflection factor has the thickness of ITO near 200nm from drawing 4 .
[0008] In use of an actual liquid crystal device, the effective refractive index changes in operating a liquid crystal device. Drawing 8 is as a result of [ of the light reflex property at the time of changing the thickness of an insulator layer, and the effective refractive index of a liquid crystal layer ] a simulation. ITO thickness is 110nm, a refractive index is 1.7, and other conditions are the same as the case of drawing 7 . As for the effective refractive index of a liquid crystal layer, and the Z-axis, the thickness of an insulator layer and the X-axis express [ a Y-axis ] the rate of a light reflex. Even if the saddle point of the rate of a light reflex exists [ the thickness of an insulator layer ] near 70nm and the effective refractive index of a liquid crystal layer changes from drawing 8 , high light transmittance is realized stably.
[0009] Drawing 9 is as a result of [ of the light reflex property at the time of changing the thickness of ITO, and the thickness of an insulator layer in a liquid crystal device ] a simulation. The refractive index of ITO is 1.7 and other conditions are the same as the case of drawing 7 . Y-axes are [ the thickness of ITO and the X-axis of the thickness of an insulator layer and the Z-axis ] the rates of a light reflex. The saddle point of the rate of a light reflex exists from drawing 9 , it is expressed with linear expression Y=aX+b, and it turns out that 60+190n or a-0.6, and b of a-0.4 and b are 170+190n (n is an integer). That is, if the group of the ITO thickness which fills the relation of this linear expression about, and insulator layer thickness is chosen, light transmittance serves as max and is stable also to fluctuation of thickness. This conditional expression cannot be used if wavelength changes, since it is a time of the wavelength of incident light being 650nm. If it takes into consideration that there is a scaling in thin film thickness and wavelength as explanation of the light transmission property of the thin film of the conventional technique described, a previous linear expression will be set to Y=aX+bxlambda /650 (wavelength of the incident light lambda was described to be per nm), and will be generalized to operating wavelength. Of course, the thickness of the orientation film is also doubled lambda/650 in that

case.
[0010] In the previous simulation, it calculated from the thin film matrix method which is well-known technique (from 49 pages to for example, the Junpei work in a crossing, the optical introduction 2, Asakura Publishing, and 53 pages). This calculates the whole thin film matrix by the multiplication of each thin film matrix, when the matrix of 2x2 described from the refractive index n of a thin film, thickness d, and the operating wavelength lambda describes the optical transfer characteristics of a thin film and the laminating of the thin film is carried out, if it says simply. It is the technique of calculating the rate of a light reflex, or light transmittance from the result.
[0011]
[Embodiment of the Invention] An example of the operation gestalt of this invention is shown in drawing 1 . The liquid crystal devices of this invention are the following configurations. That is, the glass substrate 101 ITO102 and whose orientation film 104 are the transparence substrates of the pair by which the laminating was carried out one by one comes to meet, and it has the liquid crystal layer 105 between the orientation film 104 concerned, and it is the configuration that the insulator layer 103 was formed between the orientation film 104 on one [ at least ] transparence substrate, and ITO102, and the liquid crystal device for modulating the phase of the homogeneous light or laser light as an application is considered as the fundamental configuration. By this invention, by 3000nm or more 8000nm or less, an effective refractive index [ especially as opposed to the incident light of a liquid crystal molecule ] changes in the or more 1.4 1.8 or less range, and liquid crystal thickness the refractive index to incident light Said transparence substrate has the greatest description at the place which offers the liquid crystal device characterized by for 1.75**0.1 and the orientation film being [ for 1.7**0.1 and an insulator layer ] 1.63**0.1 for 1.5**0.2 and ITO, and orientation thickness being 70**30nm. Furthermore, with the gestalt of this operation, optimization is attained in the conditions as follows in detail. namely, the glass substrate 101 — for 0.7mm in a refractive index 1.49 and thickness, and ITO102, as for 70nm in a refractive index 1.63 and thickness, and the liquid crystal layer 105, a refractive index 1.75, thickness Xnm, and the orientation film 104 is [ a refractive index 1.7, thickness Ynm, and an insulator layer 103 / the effective refractive index of the until / 1.5 to 1.7 / adjustable and thickness ] 5000nm. The thickness Y of ITO102 and the thickness X of an insulator layer 103 fill the following relational expression here. Y=aX+bxlambda /650. a-0.4 and b are the wavelength of the incident light 60+190n or a-0.6, and b were described by 170+190n (n is an integer), and lambda was described to be per nm here. Furthermore, it is used for the optical pickup equipped with the laser light source, the objective lens, and the liquid crystal device for aberration amendment as an application using the liquid crystal device of the above-mentioned publication, offer of the liquid crystal device by which permeability was optimized by the optimum conditions of the proper of each configuration of said liquid crystal device is enabled, and it can become still more possible to satisfy the function as an optical pickup using this liquid crystal device.
[0012] (Example) The example of this invention is shown in drawing 2 . a glass substrate 201 — 0.7mm in a refractive index 1.49 and thickness, and ITO202 — 120nm in a refractive index 1.7 and thickness, and an insulator layer 203 — 70nm in a refractive index 1.75 and thickness, and the orientation film 204 — as for 70nm in a refractive index 1.63 and thickness, and the liquid crystal layer 205, permeability is optimized [ the wavelength of incident light ] for the refractive index to 650nm to the until [ 1.5 to 1.7 ] adjustable by 5000nm, as for thickness.
[0013] Drawing 3 is a light reflex property over light with a wavelength of 650nm in the liquid crystal device of drawing 2 , an axis of abscissa is the effective refractive index of liquid crystal, and an axis of ordinate is a rate of a light reflex. Even if the effective refractive index of liquid crystal changes from drawing 3 , fluctuation of a reflection factor is understood are pressed down to about 1% at the maximum. Therefore, if a nonreflective coat is given to the glass substrate of this liquid crystal device, 99% or more of permeability can be obtained theoretically.
[0014] Drawing 4 shows other examples of this invention. a glass substrate 401 — 0.7mm in a refractive index 1.49 and thickness, and ITO402 — 74nm in a refractive index 1.7 and thickness, and an insulator layer 403 — 43nm in a refractive index 1.75 and thickness, and the orientation

film 404 — as for 43nm in a refractive index 1.63 and thickness, and the liquid crystal layer 405, permeability is optimized [ the wavelength of incident light ] for the refractive index to 400nm to the until [ 1.5 to 1.7 ] adjustable by 5000nm, as for thickness. That is, the scaling mentioned above in the liquid crystal device of the structure of drawing 2 is performed, the refractive index of each film does not change but thickness has become 400/650 time. However, since a glass substrate is not a thin film, the scaling is meaningless. Moreover, although liquid crystal thickness originally needs a scaling, since thickness is decided as there being refractive-index fluctuation at the time of a drive from the optical conditions to be used, the object of a scaling has not carried out.

[0015] Drawing 5 is other examples of this invention, and is applied to the pickup optical system of the optical disk equipped with the well-known liquid crystal aberration amendment device. Laser light 502 which carried out outgoing radiation from the laser light source 501 with a wavelength of 650nm is made into parallel light with a collimate lens 503, penetrates a liquid crystal device 504, and is condensed on an optical disk 506 with an objective lens 505. ITO of a liquid crystal device 504 is constituted by the division electrode, and can display the pattern of arbitration. When the substrate of an optical disk inclines, or thickness changes and light wave side aberration occurs, a liquid crystal device 504 is driven with the aberration amendment signal 507, and aberration amendment is performed serially. Since the optical structure of a liquid crystal device 504 is the same as the component of drawing 2 , even if it drives with the aberration amendment signal 507, fluctuation of light transmittance is 1% or less, and the theoretical light transmittance at the time of giving a nonreflective coat to the glass substrate of a liquid crystal device 504 is 99% or more.

[0016] Drawing 10 is drawing showing the light reflex property of the liquid crystal optical element by this invention. 1.9 was used as a refractive index of ITO. Other conditions are the same as the liquid crystal optical element by this invention. Compared with drawing 8 in connection with this invention, a reflection factor reaches also to a maximum of 10%, and a saddle point with little reflection factor fluctuation in a liquid crystal drive cannot be seen clearly, either.

[0017] Next, drawing 11 is drawing showing the light reflex property of the liquid crystal optical element by this invention. Thickness of ITO was set to 170nm. Other conditions are the same as the liquid crystal optical element by this invention. It compares drawing 3 and it turns out that the reflection factor is sharply changed [ which is concerned with this invention ] with 2% or more. Therefore, the above explanation shows that optimization of each components which constitute a liquid crystal device is important.

---

[Translation done.]

---

## DESCRIPTION OF DRAWINGS

---

[Brief Description of the Drawings]
[Drawing 1] It is the example which showed the operation gestalt in this invention.
[Drawing 2] It is an example in this invention.
[Drawing 3] It is drawing showing the light reflex property of the liquid crystal device by this invention.
[Drawing 4] They are other examples in this invention.
[Drawing 5] They are other examples in this invention.
[Drawing 6] It is the phase modulation principle Fig. of an parallel orientation mold liquid crystal device.
[Drawing 7] It is drawing showing the light reflex property of a liquid crystal device.
[Drawing 8] It is drawing showing the light reflex property of a liquid crystal device.
[Drawing 9] It is drawing showing the light reflex property of a liquid crystal device.
[Drawing 10] It is drawing showing the light reflex property of a liquid crystal device.
[Drawing 11] It is drawing showing the light reflex property of a liquid crystal device.
[Description of Notations]
101 Glass Substrate
102 ITO
103 Insulator Layer
104 Orientation Film
105 Liquid Crystal Layer
501 Laser Light Source
502 Laser Light
503 Collimate Lens
504 Liquid Crystal Device
505 Objective Lens
506 Optical Disk
507 Aberration Amendment Signal
602 Liquid Crystal Molecule
603 Linearly Polarized Light

---

[Translation done.]

## DRAWINGS

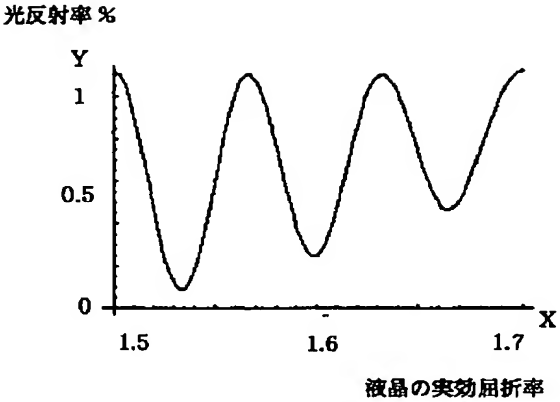
[Drawing 1]

| |
|---|
| ガラス基板１０１ |
| ITO(透明導電膜) １０２ |
| 絶縁膜１０３ |
| 配向膜１０４ |
| 液晶層１０５ |
| 配向膜１０４ |
| ITO(透明導電膜) １０２ |
| ガラス基板１０１ |

[Drawing 2]

| |
|---|
| ガラス基板２０１ |
| ITO(透明導電膜) ２０２ |
| 絶縁膜２０３ |
| 配向膜２０４ |
| 液晶層２０５ |
| 配向膜２０４ |
| ITO(透明導電膜) ２０２ |
| ガラス基板２０１ |

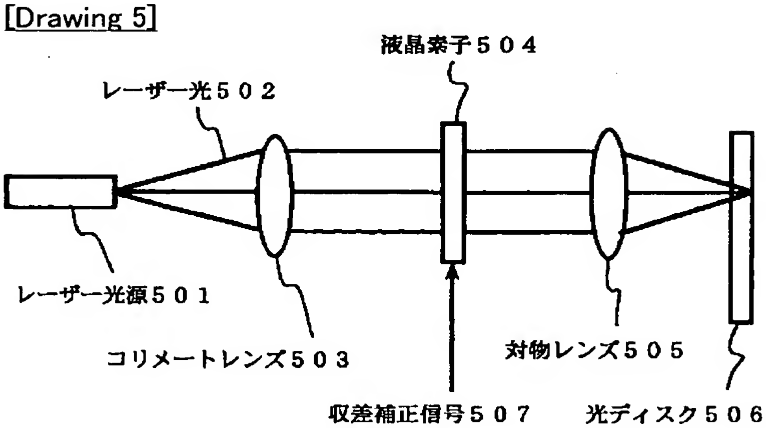
[Drawing 3]



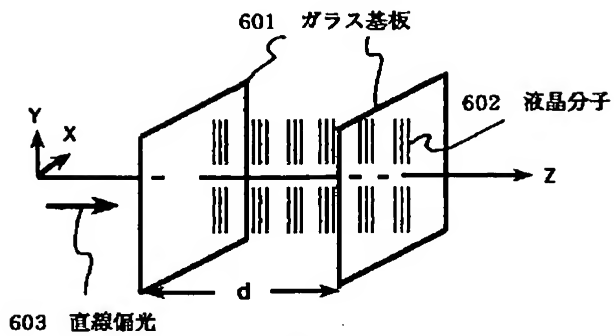

[Drawing 4]

| |
|---|
| ガラス基板４０１ |
| ITO(透明導電膜) ４０２ |
| 絶縁膜４０３ |
| 配向膜４０４ |
| 液晶層４０５ |
| 配向膜４０４ |
| ITO(透明導電膜) ４０２ |
| ガラス基板４０１ |

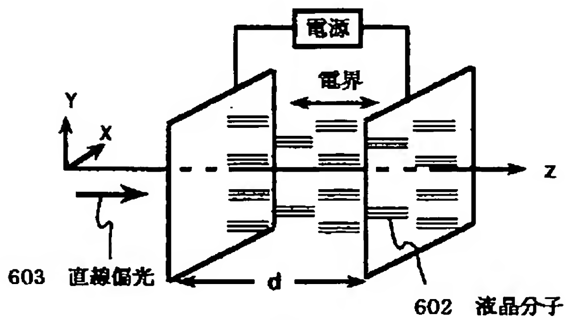
[Drawing 5]




[Drawing 6]

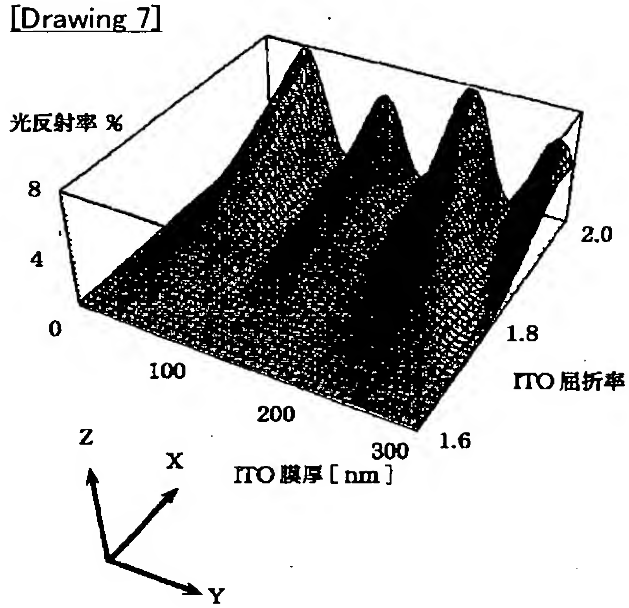



(a)

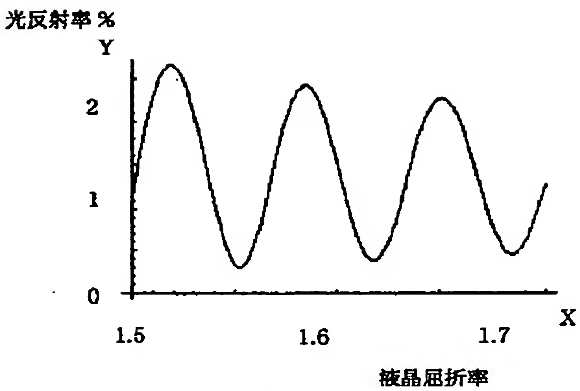



(b)

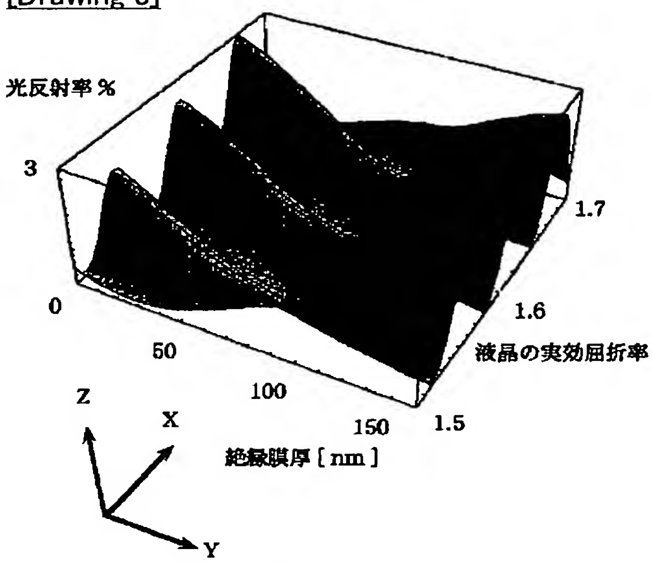
[Drawing 7]



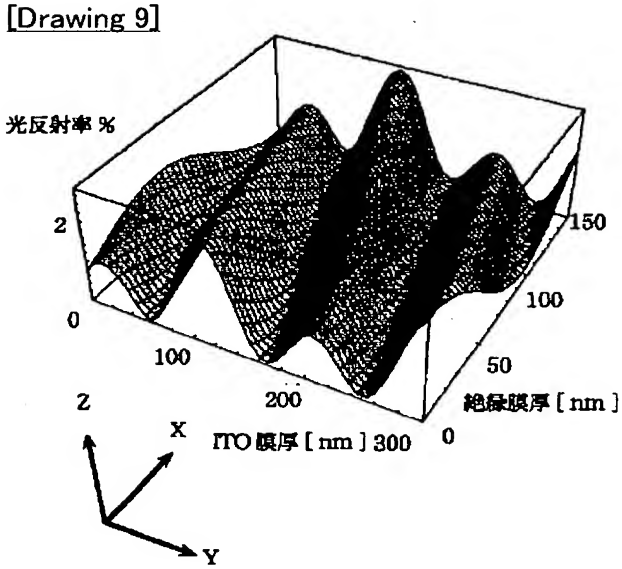

[Drawing 11]



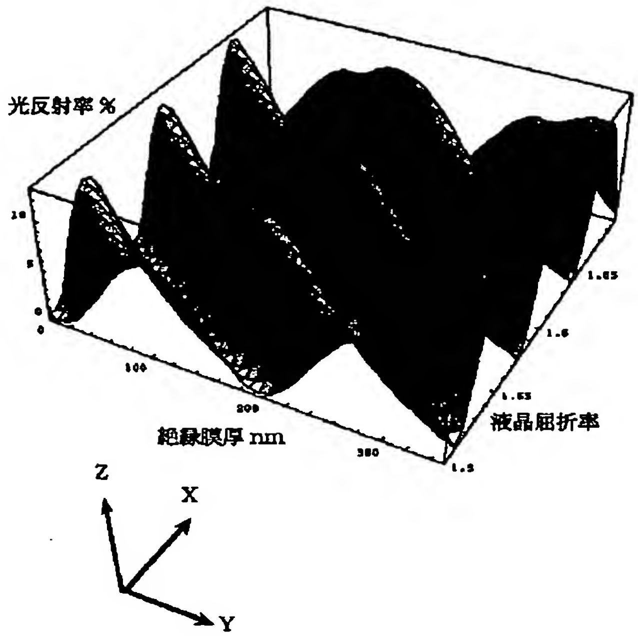

[Drawing 8]




[Drawing 9]




[Drawing 10]




[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号
特開2002－208158
（P2002－208158A）
(43)公開日　平成14年7月26日(2002.7.26)

| (51)Int.Cl.⁷ | 識別記号 | ＦＩ | | テーマコード゛(参考) |
|---|---|---|---|---|
| Ｇ１１Ｂ　7/135 | | Ｇ１１Ｂ　7/135 | Ａ | ２Ｈ０８８ |
| Ｇ０２Ｆ　1/13 | ５０５ | Ｇ０２Ｆ　1/13 | ５０５ | ５Ｄ１１９ |

審査請求　未請求　請求項の数４　ＯＬ　（全 ７ 頁）

(21)出願番号　特願2001－3194(P2001－3194)

(22)出願日　平成13年1月11日(2001.1.11)

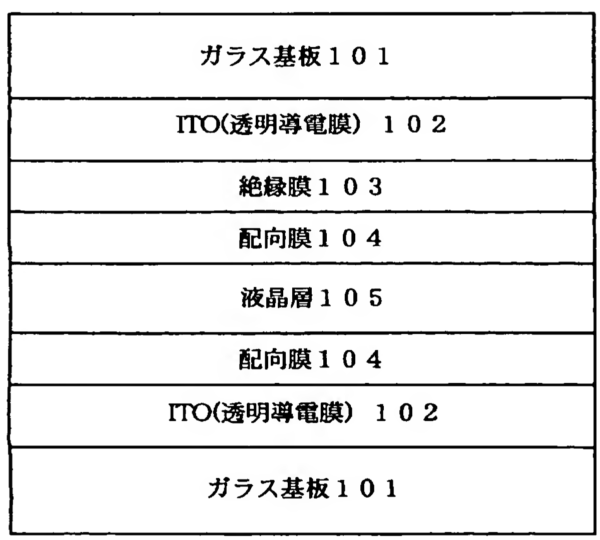
(71)出願人　000001960
シチズン時計株式会社
東京都西東京市田無町六丁目1番12号

(72)発明者　橋本　信幸
埼玉県所沢市大字下富字武野840番地　シチズン時計株式会社技術研究所内

Ｆターム(参考)　2H088 EA49 KA01 KA05 MA20
5D119 AA19 EC13 JA70

(54)【発明の名称】　液晶素子とそれを用いた光ピックアップ

(57)【要約】
【課題】　液晶素子の薄膜構造を最適化し、特定の波長に対して高い光透過率と液晶駆動時における光透過率変動を最小化する。
【解決手段】　液晶素子を構成するＩＴＯ、絶縁膜、配向膜の膜厚と屈折率の関係を最適化した。



【特許請求の範囲】

【請求項１】　ＩＴＯと配向膜とが順次積層された一対の透明基板が対面してなり、当該配向膜との間に液晶層を備え、少なくとも一方の透明基板上の配向膜とＩＴＯの間には絶縁膜が形成された単色光あるいはレーザー光の位相を変調するための液晶素子であって、前記液晶層厚が３０００ｎｍ以上８０００ｎｍ以下で、液晶分子の入射光に対する実効屈折率が１．４以上１．８以下の範囲で変化し、入射光に対する屈折率は、前記透明基板が１．５±０．２、ＩＴＯが１．７±０．１、絶縁膜が１．７５±０．１、配向膜が１．６３±０．１で、かつ、配向膜厚が７０±３０ｎｍであることを特徴とする液晶素子。

【請求項２】　前記ＩＴＯの膜厚Ｙｎｍと、前記絶縁膜の膜厚Ｘｎｍとの関係は、およそＹ＝ａＸ＋ｂ×λ÷６５０（λはｎｍ単位で記述された入射光の波長）を満たし、ａは－０．４、ｂは６０＋１９０ｎあるいはａは－０．６、ｂは１７０＋１９０ｎ（ｎは整数）である事を特徴とした請求項１に記載の液晶素子。

【請求項３】　前記ＩＴＯの膜厚が（１２０±３０）×λ÷６５０ｎｍ、絶縁膜厚が（７０±３０）×λ÷６５０ｎｍである事を特徴とした請求項１に記載の液晶素子。

【請求項４】　収差補正用の液晶素子を備えた光ピックアップにおいて、前記液晶素子が請求項１乃至請求項３のいずれか１項に記載の液晶素子であることを特徴する液晶素子を用いた光ピックアップ。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】収差補正用の液晶素子とそれを備えた光ピックアップに関する。

【０００２】

【従来の技術】従来技術の理解を容易にするため、公知である光学薄膜の光透過特性及び液晶素子の光学的な構造、及び液晶素子を用いた光の位相変調について簡単に解説する。まず最初にガラス基板などの透明な基板上に透明な薄膜を一層あるいは多層に塗布した光学薄膜素子を考える。このとき透明な材料で構成されるので光透過率は波長に関係なく一定でおよそ１００％となる。しかし実際にはガラス基板を含むすべての薄膜の屈折率が同一である場合を除き、光の干渉効果で光透過率は透明基板と各薄膜の屈折率及び各薄膜の厚みと光の波長λにより決定される。すなわち波長により透過率が異なる。そのため特定の条件においては、特定の波長のみを透過する光学薄膜素子が実現可能で干渉フィルターとして良く知られる。また透過率に関して薄膜の膜厚と波長にはスケーリングが存在する。すなわち波長がｎ分の１になったとき薄膜の膜厚もｎ分の１にすれば透過率は同じである。

【０００３】次に一般的な液晶素子の光学構造について



説明する。主構成要素としてガラス基板、ＩＴＯ（透明導電膜）、絶縁膜、配向膜、液晶層、配向膜、ＩＴＯ、ガラス基板の順に構成される。ガラス基板は屈折率が１．５程度のガラスが使用される。また量産性や材料の制約等によりＩＴＯは屈折率が１．７から２程度、膜厚は１００から３０００ｎｍ程度、絶縁膜は屈折率が１．７程度、膜厚が５０から３００ｎｍ程度、配向膜は屈折率が１．６３程度、膜厚が５０から２００ｎｍ程度が使用され薄膜構造を持っている。続いて平行配向型あるいは垂直配向型液晶素子を用いた光の位相変調原理について解説する。図６（ａ）、（ｂ）は平行配向型液晶素子の動作を模式的に表したものである。図６（ａ）のように透明導電膜が塗布されたガラス基板６０１の間に液晶分子６０２が挟まれその膜厚はｄである。両方のガラス基板６０１とも配向軸方向はＹ軸方向のため、液晶分子６０２はその長軸方向をＹ軸方向に揃え平行に並んでいる。この液晶素子にＹ軸方向の直線偏光６０３が入射すると液晶分子６０２の長軸方向を見ながら進むためその光路長はｎ１×ｄとなる。ここでｎ１は液晶分子６０２の長軸方向の屈折率で、直線偏光６０３に対する実効屈折率となる。

【０００４】次に図６（ｂ）に示すようにＺ軸方向に十分高い電界を与えると液晶分子６０２はその長軸を電界方向にそろえて並ぶ。この液晶素子にＹ軸方向の直線偏光６０３が入射すると液晶分子６０２の短軸方向を見ながら進むためその光路長はｎ２×ｄとなる。ここでｎ２は液晶分子６０２の短軸方向の屈折率である。従って電界を与える前後で光路長が（ｎ１－ｎ２）×ｄだけ変化し、入射直線偏光６０３の位相が２π（ｎ１－ｎ２）×ｄ÷λ（λは入射光の波長）だけ変化して出射する。液晶分子に与える電界を調節する事で中間状態も実現可能である。従って、分割した透明電極や高抵抗電極により生じる勾配電界等を用いて液晶分子を部分的に駆動すれば、入射直線偏光６０３に対して位相分布を与える事が可能である。また垂直配向された液晶素子においてもその基本動作は同じであるが、電界を与えない時が図６（ｂ）の状態で電界を与えたときが図６（ａ）の状態となる。

【０００５】近年、ＤＶＤなどの高密度の光ディスクにおいて、光学系の収差補正素子として液晶素子が注目されている。これはレーザー光源と対物レンズを備えた光ピックアップの光路中に液晶素子を挿入し、光ディスク基板が傾むく事により発生するコマ収差や、多層ディスク基板を読むさいに発生する球面収差による光の位相乱れ、すなわち光の波面の乱れを補正しようとするものである。このとき発生する収差量に応じて、分割された透明電極により液晶素子に屈折率分布を与えてレーザー光の波面を補正する。

【０００６】

【発明が解決しようとする課題】しかるに光ピックアッ

プのようにレーザーパワーの限られたレーザ光学系用の光学素子では光透過率は重要な要素である。特に最近注目される波長４５０ｎｍ程度の青色レーザーを用いた光ピックアップの場合、青色レーザーの発光効率は従来の波長６５０ｎｍ程度の赤色レーザーに比べ低下する。またレーザー光は特定の鋭い波長の光を発生するため、その波長における光透過率が重要となる。他方で液晶素子は薄膜構造を持ち更に駆動する事で液晶層の実効屈折率が変化する。そのためレーザー光や単色光で使用する場合、使用する波長に対して液晶素子の薄膜構造を最適化して透過率が最大となるように、また液晶を駆動しても光透過率の変動が最小となるようにするのが望ましい。しかるに、従来の液晶素子は位相変調素子としてではなく、偏光板と共に用いる事で白色光に対する光シャッタ効果を利用した表示用途を主体に開発されてきた。そのため、液晶素子の薄膜構造はレーザー光学系に対して最適化設計されてこなかった。また一般のレーザー光学系用に位相変調型である平行配向型液晶がしばしば使用されてきたが、一般にレーザー光は非常に大きなパワーを持つため光透過率を問題とする必要はなく液晶素子の薄膜構造を最適化する必要はなかった。

【０００７】

【課題を解決するための手段】図７に液晶素子においてＩＴＯの厚みと屈折率を変化させた場合の、波長６５０ｎｍの単色光における光反射特性のシュミレーション結果を示す。液晶素子としてはガラス基板、ＩＴＯ、絶縁膜、配向膜、液晶層、配向膜、ＩＴＯ、ガラス基板の順で構成される。ガラス基板の屈折率は１．４９、絶縁膜の屈折率は１．７５、厚みは７０ｎｍ、配向膜の屈折率は１．６３、厚みは７０ｎｍ、液晶層の実効屈折率は１．６、厚みは５０００ｎｍである。図７でＹ軸はＩＴＯの膜厚、Ｘ軸はＩＴＯの屈折率、Ｚ軸は光反射率を表す。図７からＩＴＯの厚みが１１０ｎｍ付近に第１の反射率の極小値があり、ＩＴＯの屈折率が変化しても安定である。またＩＴＯの屈折率が１．６に近いほど反射率が低下し、かつＩＴＯ膜厚の変化に対する変動も小さくなる。したがって本条件下においてはＩＴＯの膜厚が１１０ｎｍ、その屈折率が１．６で光透過率は最大かつ安定となるが現実にはＩＴＯ屈折率として選べる値は１．７である。また図4よりＩＴＯの厚みが２００ｎｍ付近に第２の反射率の極小値がある事もわかる。

【０００８】実際の液晶素子の使用においては、液晶素子を動作させることでその実効屈折率が変化する。図８は絶縁膜の膜厚と液晶層の実効屈折率を変化させた場合の光反射特性のシュミレーション結果である。ＩＴＯ膜厚は１１０ｎｍ、屈折率は１．７であり他の条件は図７の場合と同じである。Ｙ軸が絶縁膜の膜厚、Ｘ軸が液晶層の実効屈折率、Ｚ軸は光反射率を表す。図８より絶縁膜の膜厚が７０ｎｍ付近に光反射率の鞍部点が存在し、液晶層の実効屈折率が変化しても高い光透過率が安定的に実現される。

【０００９】図９は液晶素子においてＩＴＯの膜厚と絶縁膜の膜厚を変化させた場合の光反射特性のシュミレーション結果である。ＩＴＯの屈折率は１．７であり、他の条件は図７の場合と同じである。Ｙ軸がＩＴＯの膜厚、Ｘ軸が絶縁膜の膜厚、Ｚ軸は光反射率である。図９より光反射率の鞍部点が存在し一次式Ｙ＝ａＸ＋ｂで表され、ａは－０．４、ｂは６０＋１９０ｎあるいはａは－０．６、ｂは１７０＋１９０ｎ（ｎは整数）である事がわかる。すなわちおよそこの一次式の関係を満たすＩＴＯ膜厚と絶縁膜厚の組を選べば光透過率は最大となり、かつ膜厚の変動に対しても安定である。この条件式は入射光の波長が６５０ｎｍのときであるため波長が変われば使用できない。従来技術の薄膜の光透過特性の説明で述べたように、薄膜厚と波長にはスケーリングがある事を考慮すれば先の一次式はＹ＝ａＸ＋ｂ×λ÷６５０（λはｎｍ単位で記述された入射光の波長）となり使用波長に対し一般化される。もちろん、そのさい配向膜の膜厚もλ÷６５０倍する。

【００１０】先のシュミレーションにおいては公知の手法（例えば辻内順平著、光学概論２、朝倉書店、４９頁から５３頁）である薄膜マトリクス法から計算した。これは簡単にいうなら薄膜の屈折率ｎ、厚みｄ、使用波長λから記述される２×２のマトリクスで薄膜の光学伝達特性を記述し、薄膜が積層された場合は各薄膜マトリクスの乗算で全体の薄膜マトリクスを計算する。その結果から光反射率あるいは光透過率を計算する手法である。

【００１１】

【発明の実施の形態】図１に本発明の実施形態の一例を示す。本発明の液晶素子は以下の構成である。すなわち、ＩＴＯ１０２と配向膜１０４とが順次積層された一対の透明基板であるガラス基板１０１が対面してなり、当該配向膜１０４との間に液晶層１０５を備え、少なくとも一方の透明基板上の配向膜１０４とＩＴＯ１０２の間には絶縁膜１０３が形成された構成であり、用途としては単色光あるいはレーザー光の位相を変調するための液晶素子を基本的構成としている。特に本発明では、液晶層厚が３０００ｎｍ以上８０００ｎｍ以下で、液晶分子の入射光に対する実効屈折率が１．４以上１．８以下の範囲で変化し、入射光に対する屈折率は、前記透明基板が１．５±０．２、ＩＴＯが１．７±０．１、絶縁膜が１．７５±０．１、配向膜が１．６３±０．１で、かつ、配向膜厚が７０±３０ｎｍであることを特徴とする液晶素子を提供するところに最大の特徴を持っている。更に詳しくは、本実施の形態では以下の通りの条件において最適化を図っている。すなわち、ガラス基板１０１は屈折率１．４９、厚さ０．７ｍｍ、ＩＴＯ１０２は屈折率１．７、厚さＹｎｍ、絶縁膜１０３は屈折率１．７５、厚さＸｎｍ、配向膜１０４は屈折率１．６３、厚さ７０ｎｍ、液晶層１０５は実効屈折率が１．５から１．

７まで可変、厚さは５０００ｎｍである。ここでＩＴＯ１０２の膜厚Ｙと絶縁膜１０３の膜厚Ｘは次の関係式を満たす。Ｙ＝ａＸ＋ｂ×λ÷６５０。ここでａは－０．４、ｂは６０＋１９０ｎあるいはａは－０．６、ｂは１７０＋１９０ｎ（ｎは整数）でλはｎｍ単位で記述された入射光の波長である。さらに、上記記載の液晶素子を用いた応用例としては、レーザ光源と、対物レンズと、収差補正用の液晶素子とを備えた光ピックアップに用いられ、前記液晶素子の個々の構成の固有の最適条件により、透過率が最適化された液晶素子を提供可能とし、さらに、この液晶素子を用いた光ピックアップとしての機能を満足することが可能となりうる。

【００１２】(実施例)図２に本発明の実施例を示す。ガラス基板２０１は屈折率１．４９、厚さ０．７ｍｍ、ＩＴＯ２０２は屈折率１．７、厚さ１２０ｎｍ、絶縁膜２０３は屈折率１．７５、厚さ７０ｎｍ、配向膜２０４は屈折率１．６３、厚さ７０ｎｍ、液晶層２０５は屈折率が１．５から１．７まで可変、厚さは５０００ｎｍで入射光の波長は６５０ｎｍに対して透過率が最適化されている。

【００１３】図３は図２の液晶素子において波長６５０ｎｍの光に対する光反射特性で、横軸が液晶の実効屈折率、縦軸が光反射率である。図３より液晶の実効屈折率が変化しても反射率の変動は最大で１％程度に押さえられているのがわかる。従って本液晶素子のガラス基板に無反射コートを施せば理論上９９％以上の透過率を得る事ができる。

【００１４】図４は本発明の他の実施例を示す。ガラス基板４０１は屈折率１．４９、厚さ０．７ｍｍ、ＩＴＯ４０２は屈折率１．７、厚さ７４ｎｍ、絶縁膜４０３は屈折率１．７５、厚さ４３ｎｍ、配向膜４０４は屈折率１．６３、厚さ４３ｎｍ、液晶層４０５は屈折率が１．５から１．７まで可変、厚さは５０００ｎｍで入射光の波長は４００ｎｍに対して透過率が最適化されている。すなわち図２の構造の液晶素子に前述したスケーリングを施したものであり各膜の屈折率は変わらず、膜厚が６５０分の４００倍となっている。ただしガラス基板は薄膜でないためスケーリングは無意味である。また液晶層厚は本来スケーリングが必要であるが、駆動時に屈折率変動がある事と、使用する光学条件から膜厚が決まるためスケーリングの対象とはしていない。

【００１５】図５は本発明の他の実施例で、公知である液晶収差補正機構を備えた光ディスクのピックアップ光学系に適用したものである。波長６５０ｎｍのレーザー光源５０１から出射したレーザー光５０２がコリメートレンズ５０３で平行光にされ、液晶素子５０４を透過して対物レンズ５０５により光ディスク５０６上に集光される。液晶素子５０４のＩＴＯは分割電極により構成され任意のパターンを表示可能である。光ディスクの基板が傾いたり、厚みが変化したりして光波面収差が発生した場合は、収差補正信号５０７により液晶素子５０４を駆動して逐次収差補正を行う。液晶素子５０４の光学構造は図２の素子と同じため、収差補正信号５０７により駆動しても光透過率の変動は１％以下で、液晶素子５０４のガラス基板に無反射コートを施した場合の理論光透過率は９９％以上である。

【００１６】図１０は本発明によらない液晶光学素子の光反射特性を表す図である。ＩＴＯの屈折率として１．９を用いた。他の条件は本発明による液晶光学素子と同じである。本発明に関わる図８と比べ、反射率が最大１０％にも達し、また液晶駆動における反射率変動の少ない鞍部点もはっきりとは見受けられない。

【００１７】次に、図１１は本発明によらない液晶光学素子の光反射特性を表す図である。ＩＴＯの膜厚を１７０ｎｍとした。他の条件は本発明による液晶光学素子と同じである。本発明に関わる図３比べ、反射率が２％以上と大きく変動しているのがわかる。従って、以上の説明から、液晶素子を構成する個々の部品の最適化が重要であることがわかる。

【００１８】

【発明の効果】今までの説明から明らかなように、本発明による液晶素子を用いれば任意の単色光に対して、光透過率を最適化可能である。すなわち、高い光透過率と液晶を駆動したときでも光透過率の変動を低く押さえる事ができる。また液晶素子の製作において膜厚が多少変動しても透過率変化が少ない。本液晶素子は光ディスクのピックアップやレーザープリンタ等の光学系の収差補正素子や光波面制御素子として使用すれば、光学系の光利用効率が高くなり機器の低電力化にも貢献する。

【００１９】また、本発明では液晶素子は特定の波長に対して最適化したが、複数の波長に対して最適化する事も可能である。その場合は、単色での最適化よりは性能は低下する。

【図面の簡単な説明】

【図１】本発明における実施形態を示した例である。

【図２】本発明における実施例である。

【図３】本発明による液晶素子の光反射特性を表す図である。

【図４】本発明における他の実施例である。

【図５】本発明における他の実施例である。

【図６】平行配向型液晶素子の位相変調原理図である。

【図７】液晶素子の光反射特性を表す図である。

【図８】液晶素子の光反射特性を表す図である。

【図９】液晶素子の光反射特性を表す図である。

【図１０】液晶素子の光反射特性を表す図である。

【図１１】液晶素子の光反射特性を表す図である。

【符号の説明】

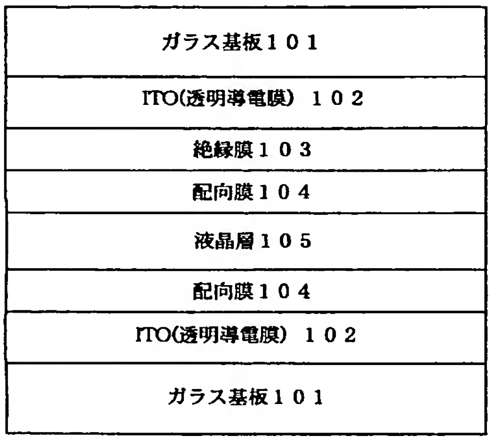
１０１ ガラス基板

１０２ ＩＴＯ

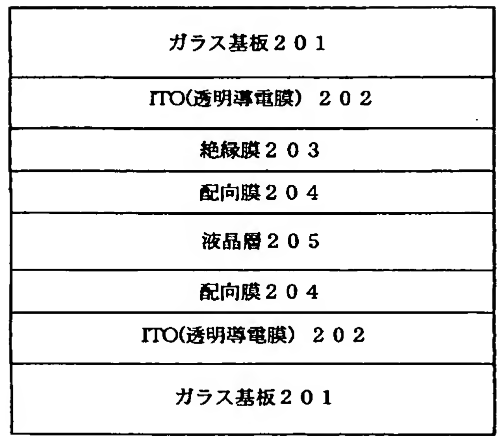
１０３ 絶縁膜

１０４　配向膜
１０５　液晶層
５０１　レーザー光源
５０２　レーザー光
５０３　コリメートレンズ
５０４　液晶素子
５０５　対物レンズ
５０６　光ディスク
５０７　収差補正信号
６０２　液晶分子
６０３　直線偏光

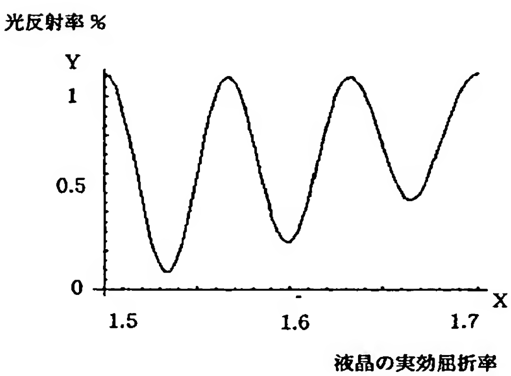
【図１】



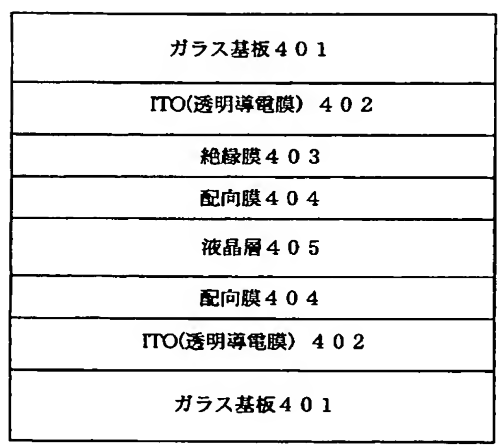

【図２】



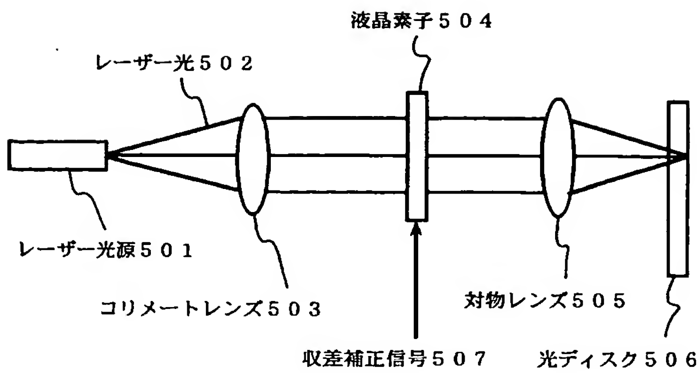

【図３】



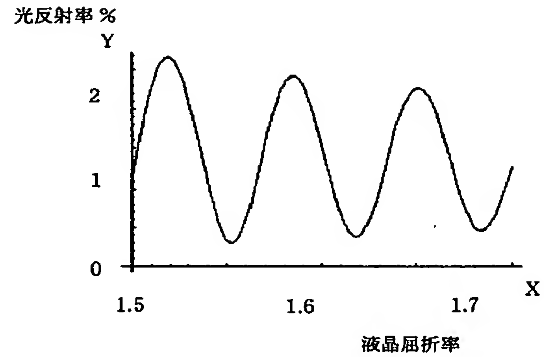

【図４】



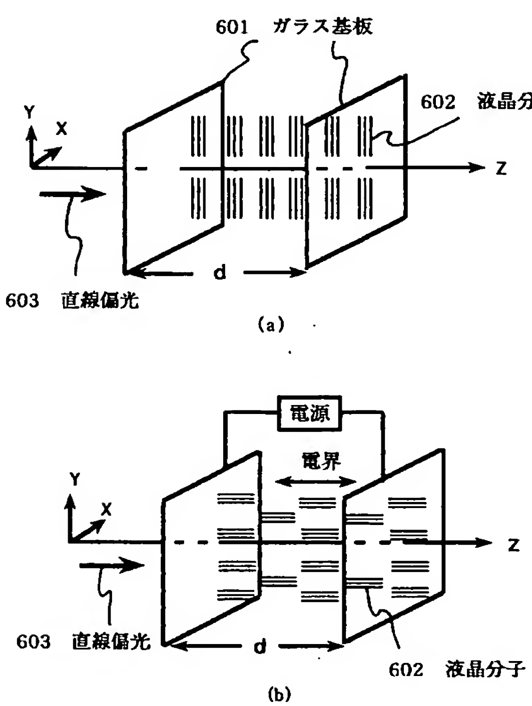
【図５】


液晶素子５０４
レーザー光５０２
レーザー光源５０１
コリメートレンズ５０３
対物レンズ５０５
収差補正信号５０７
光ディスク５０６

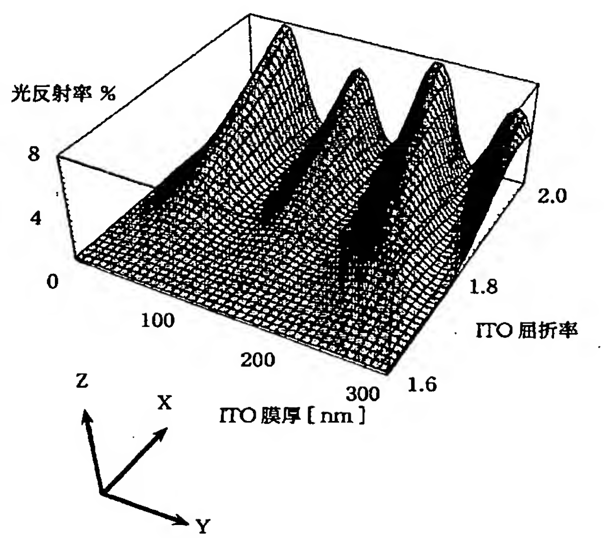
【図１１】


光反射率％
Y
2
1
0
1.5
1.6
1.7
X
液晶屈折率

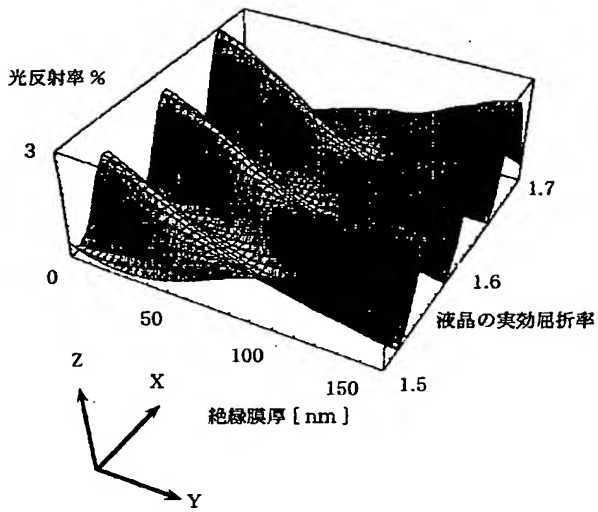
【図６】


601　ガラス基板
602　液晶分子
Y
X
Z
d
603　直線偏光
(a)
電源
電界
Y
X
Z
603　直線偏光
d
602　液晶分子
(b)

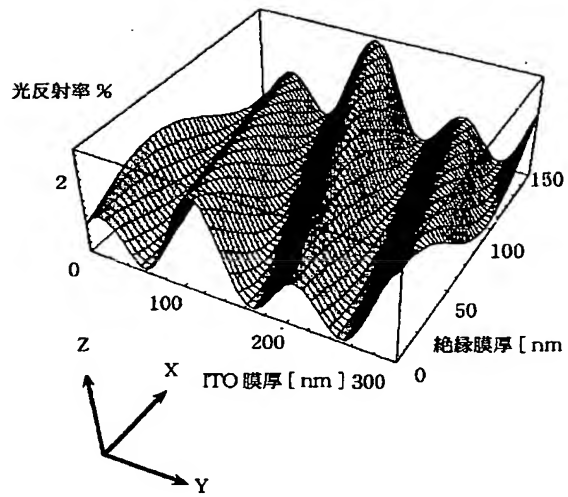
【図７】


光反射率 %
8
4
0
2.0
1.8
ITO 屈折率
1.6
100
200
300
ITO 膜厚 [ nm ]
Z
X
Y

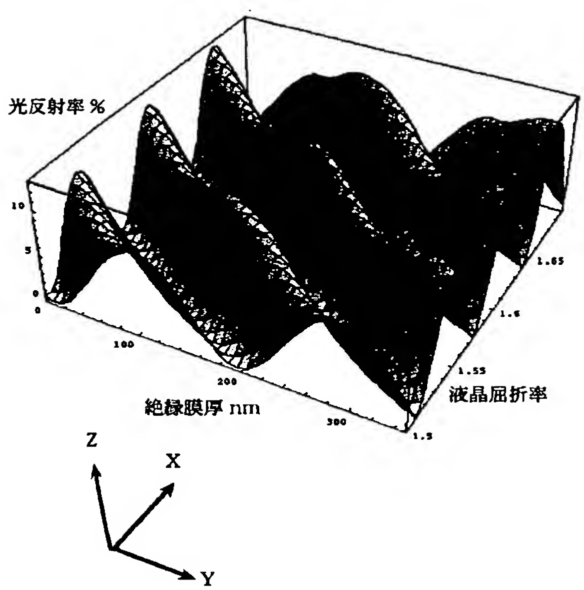
【図８】


光反射率％
3
0
50
100
150
絶縁膜厚［nm］
1.7
1.6
1.5
液晶の実効屈折率
Z
X
Y

【図９】


光反射率％
2
0
100
200
ITO膜厚［nm］300
150
100
50
0
絶縁膜厚［nm］
Z
X
Y

【図１０】


光反射率％
絶縁膜厚 nm
液晶屈折率
Z
X
Y